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The Design of Metal-Semiconductor-Metal Structure Magnetic sensor

Chalin Sutthinet [a], Toempong Phetchakul [a,*], Wittaya Luanatikomkul [a] and Amporn Poyai [b]

[a] *Department of Electronics, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand*

[b] *Thai Microelectronics Center, National Electronics and Computer Technology Center, Chachoengsao, Thailand*

Abstract

This paper presents the MSM structure magnetic detector device that normally detects the electromagnetic wave. The device is special design for magnetic field detector and still detects the electromagnetic wave as normal function. The schottky diode with the split contacts structure allows us to reach this target. The device operates with the saturation current and the magnetic response is the current difference between two contacts which is injected from one metal and deflected in semiconductor toward to another metal. From the simulation result by Sentaurus TCAD, the relative sensitivity is 14.19 mT^{-1} at the current 0.3 µA. This device is the first MSM multi-sensor for magnetic and electromagnetic wave detector.

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1. Introduction and Structure

MSM is the structure of electromagnetic detector device that composes of two schottky junction connected back to back together as metal semiconductor metal [1]. This structure is simple and low cost but shows very low

* Corresponding author.
E-mail address: toempong.ph@kmitl.ac.th

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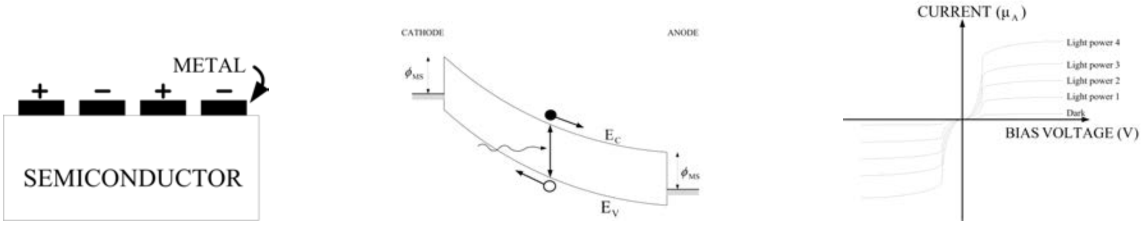
capacitance. The structure is normally designed in interdigitated structure for high sensitivity rather than rectangular or square large area. The photo current generate from the junction area under the metal and the gap between metals [2]. The bias can applied between two metals that one junction is forward and another is reverse. The interdigitated structure, energy band diagram through the active layer and photo current characteristic are shown in Figure 1.



(a) (b) (c)

Figure 1. MSM photo detector (a) The interdigitated structure MSM (b) Energy Band diagram (c) Photo current characteristics.

The dual magnetodiode is the device for magnetic detection [3,4]. The structure composed of two diodes that designed the suitable deflection length of carrier between the injected junction to contact. The anodes are commoned and two cathodes are seperated. When magnetic field is applied, the induced force from magnetic field vector cross the current vector act upon the injected carriers along the deflection length so the current of two cathodes are difference ΔI. The current difference depend linearly on the magnetic field density and the sign of ΔI is invertion when the direction of magnetic field is opposite. The diode can be fabricated as pn junction as well as schottky junction. The device can operate in forward and reverse bias and can be done both in hole and electron injected currents. Figure 2. shows the structure of dual magnetodiode and the characteristics.

(a) Top view structure (b) Characteristic of magnetodiode

Figure 2. Dual magnetodiode.

The MSM multi-sensor structure can be designed to reach this purpose because of the dual magnetodiode structure. It is the merged structure between the MSM photo detector and magnetodiode. The core of the structure is the junction so the schottky junction between metal-semiconductor is selected here rather than pn junction of magnetodiode. The metal area must use for photo absorbtion and for magnetic response so the rectangular or square shape of metal is designed. The gap between metals is defined as deflection length in the same time so the critical length is determind by the length of carrier deflection. The current difference of magnetic response is cerried out by fabricated the two contact windows W_1 and W_2 within the metal for connecting with the other metal contact layer for two seperated current response. This structure is shown in Figure 3(a) and the 2-dimensions model for simulation by Sentaurus TCAD program is shown in Figure 3(b). The area of metals are 400 x 400 μm^2 with the contact window 50 x 50 μm^2 and the gap between metals and contacts are 100 µm and 10 µm, respectively.

(a) Top view (b) 2-dimension model

Figure 3. Merged structure of MSM Magnetic sensor**.**

2. Results and Discussion

Figure 4. is the magnetic response from the simulation at room temperature 300 K. The constant current is applied from one metal to the another metal that has 2 split contact windows. The output is the current difference between contact windows $\Delta I_D = I_{D1}\text{-}I_{D2}$. When magnetic field is applied in -Z direction, the output responses are in positive with the relative sensitivities 7.9, 11.93 and 13.74 mT^{-1} at current 0.1, 0.2 and 0.3 µA, respectively. In the opposite magnetic field direction, the relative sensitivities are 8.2, 11.62 and 14.19 mT^{-1} at current 0.1, 0.2 and 0.3 µA, respectively. The current density distribution from the simulation is shown in Fig.5. While the magnetic field in -Z is applied, the induced force in –Y direction is induced and the current at the contact window 1 is greater than contact window 2, $\Delta I_D > 0$. In the opposite direction +Z, the induced force is in +Y direction and the current at contact window 1 is less than contact window 2, $\Delta I_D < 0$. Figure 6 shows the mechanism of the device according to the discussion. Although the device has two split contact windows one metal instead of two metal contacts but the mechanism still the same. The current deflects in the metal by induced force to contact windows causes the current difference ΔI_D. The output response ΔI_D is still defined as

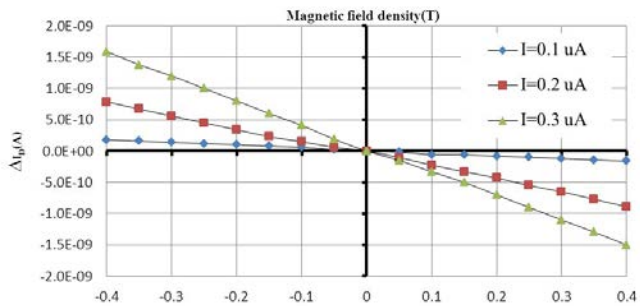
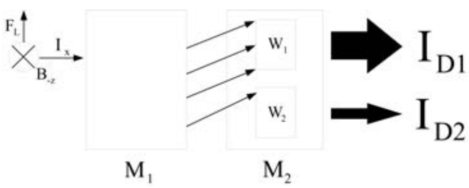


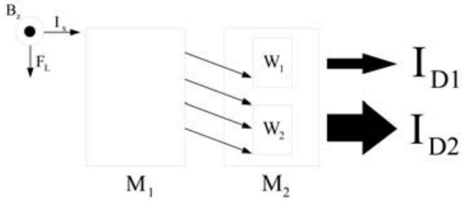
Figure 4. The magnetic field response of MSM magnetic sensor.

(a) -Z direction magnetic field (b) +Z direction magnetic field

Figure 5. The current density distribution of MSM magnetic sensor.



(a) -Z direction magnetic field



(b) +Z direction magnetic field

Figure 6. The mechanism of MSM magnetic sensor.

$$\Delta I_D = J_x.d.\Delta Y \tag{1}$$

where J_x is electron current density in X direction, ΔY is the distance of deviation current in Y direction due to Lorentz's force and d is the depth of current. The relative sensitivity S_R is defined as

$$S_R = \Delta I_D/I_D \cdot \Delta B_Z. \tag{2}$$

3. Conclusion

The MSM magnetodiode is proposed here first time. The device detects magnetic field and electromagnetic wave in the same device. The structure is based on MSM structure for photo detection and dual magnetodiode for magnetic field detection. The merged structure has two square metals that one metal are designed for two contact windows within the metal for connecting with the other metal layer for seperate current. The magnetic response is the diference of metal current from two seperate contact windows that treats the principal of dual magnetodiode for detecting the magnetic field. It is a multi-sensor that uses the MSM structure for detecting electromagnetic wave and magnetic field.

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